

Self-Adapting Botanical Tree Models in Computer Graphics

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 Jan 23rd 2014
 Indiana Horticultural Congress

Modeling

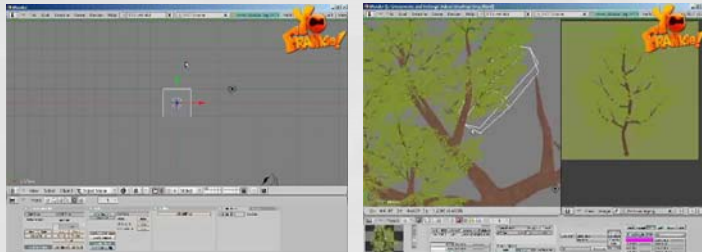


- Modeling is an open problem in CG
- Traditional approaches
 - Manually
 - Scanning (and reconstruction) of real objects
 - By a code
- How does it relate to biology?

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Modeling



Pablo Vazquez - <http://vinco.com/2956756>

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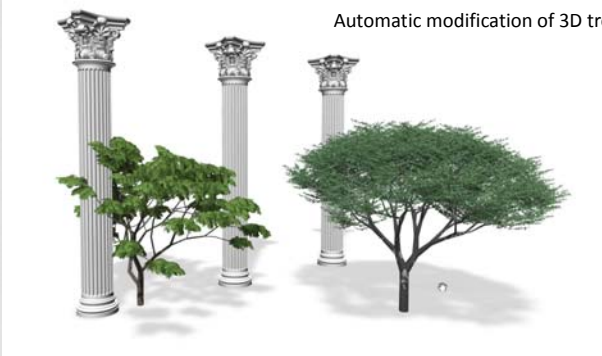
Tree models are static



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Plastic Trees



Automatic modification of 3D tree models

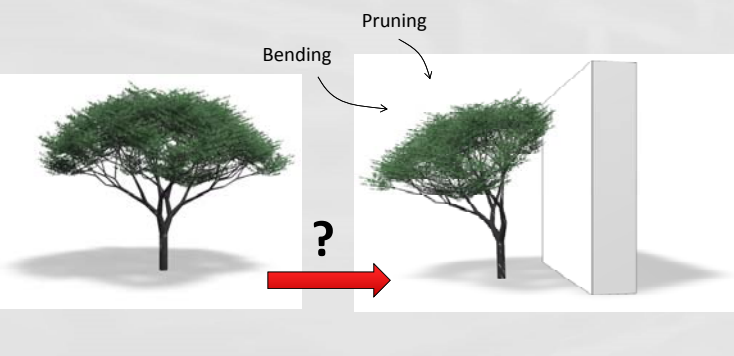
The image shows a 3D scene with three classical columns and two trees. The trees are positioned in front of the columns. The text 'Automatic modification of 3D tree models' is placed above the trees.

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Approach



The diagram illustrates the process of tree modification. On the left, a tree is shown in its original state. A red arrow points to the right, where a tree is shown after modification. The modification is labeled 'Bending' and 'Pruning'. A question mark is placed between the two trees, indicating the process. A vertical grey bar is shown to the right of the modified tree, representing a constraint or environment.

Bending

Pruning

?

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Overview


Analysis	Realization	Verification
Computing Branch Age	Tree Graph Transformations	Evaluation
Temporal Light Conditions	Modeling of Leaf-Clusters	Limitations
Inverse Tropism	Types of Interaction	Results
Pruning Estimation		

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Input



[Livny et al. 2011]

Skeletal Graph
+
Leaf Clusters


The image shows a skeletal graph of a tree branch and a cluster of leaf clusters. The text 'Skeletal Graph + Leaf Clusters' is placed to the left of the image.

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Tree Analysis



Skeletal graph:

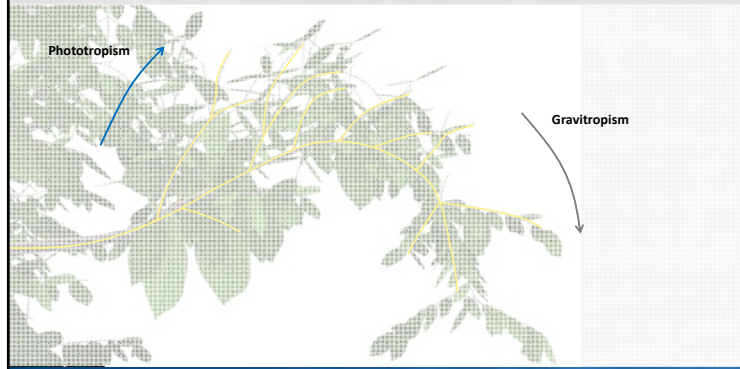
- branch age
- growth rate

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Tropism



Phototropism

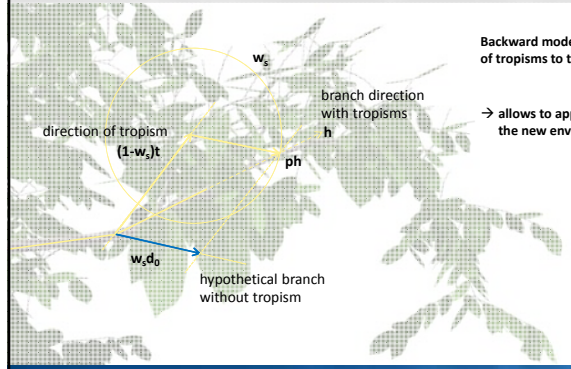
Gravitropism

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Inverse Tropism



Backward modeling to estimate influence of tropisms to the original model

→ allows to apply tropisms triggered by the new environment

direction of tropism $(1-w_s)t$

w_s

branch direction with tropisms h

ph

$w_s d_0$

hypothetical branch without tropism

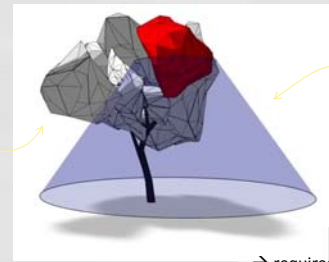
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Tree Analysis

How much light is cast onto a part of a tree?



leaf-cluster

shadow volume


→ required for bending/pruning

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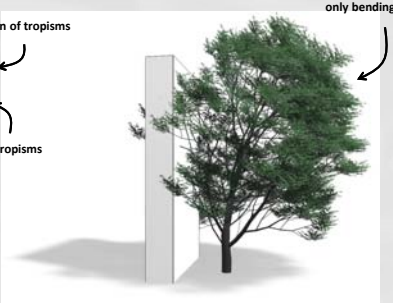
Dynamic Interaction - Bending



New Direction


$$\vec{h} = w_s \vec{d}_0 + (1 - w_s) \frac{\sum w_\tau \vec{t}_\tau}{\sum w_\tau}$$

\vec{h} : new direction
 w_s : start weight
 \vec{d}_0 : normalized direction
 w_τ : weights of tropisms
 \vec{t}_τ : combination of tropisms




Transformations represent changes in the tree growth.

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Dynamic Interaction - Pruning



Approach similar to [Palubicki et al. 2009]

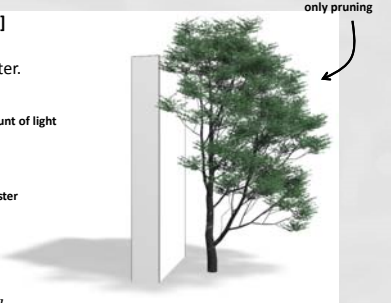
Amount of Light received by the leaf-cluster.

$$\varphi_{t_s} = \sum_{c \in \mathcal{C}_s} 2\pi r_c^2 i_c$$


φ_{t_s} : amount of resources (light)
 i_c : normalized amount of light
 r_c : radius of a given cluster

l_t : sum of distances


Branch is pruned when ratio $\varphi_{t_s}/l_t < thres$




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Dynamic Interactions




Original Model Bending Pruning Bending + Pruning Result

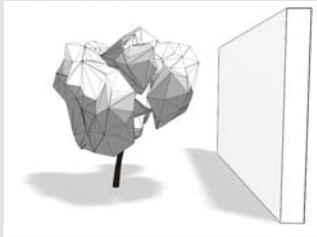
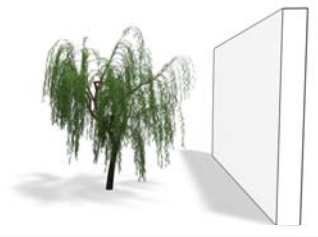


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Dynamic Interactions - Leaves




Intermediate Representation

Final Rendering

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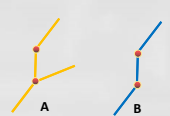
Evaluation

How to measure the distances between two trees?

Approach proposed by [Ferraro and Godin 2000] and [Zhang 1996].
Constrained edit distance between tree graphs.

Possible edit operations:


- Deletion
- Insertion
- Change



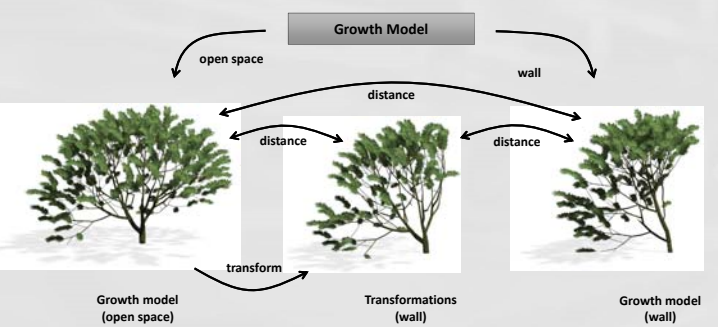
How much does the transformation from A to B cost?
→ low costs → high similarity

Dissimilarities between two trees can be measured as edit distances of the graphs.


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Evaluation



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Evaluation


	Concept	T-D	G-D	T-D	T-T
Tree A	Mean	236.29	229.65	347.19	225.38
	SD	35.27	52.71	93.33	33.94
	p-value	p = 0.46		p < 0.001	
Tree B	Mean	431.73	396.81	473.63	413.64
	SD	112.79	71.32	70.65	90.76
	p-value	p = 0.06		p = 0.001	
Tree C	Mean	756.27	841.79	927.64	550.63
	SD	266.84	239.57	207.85	83.33
	p-value	p = 0.13		p < 0.001	

No significant distance between growth and transforms.


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Tree-tree interaction



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Tree-tree interaction

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Static Models Bending and Pruning Strong Pruning Exaggerated Bending

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Detailed description: This slide illustrates the progression of tree models from static to interactive. It shows four pairs of trees. The first pair, 'Static Models', shows two separate trees. The second, 'Bending and Pruning', shows the trees leaning towards each other. The third, 'Strong Pruning', shows the trees with their overlapping branches removed. The fourth, 'Exaggerated Bending', shows the trees leaning significantly towards each other.

Tree-tree interaction

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Detailed description: This slide shows a large, detailed tree model on the left. To its right are two wireframe versions of the same tree, one showing the full structure and another showing a pruned version. Below the wireframes are two smaller, more detailed tree models, one of which appears to be a pruned version of the larger tree.

Results

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LiDAR

Xfrog

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Detailed description: This slide compares two methods of tree modeling. The 'LiDAR' row shows three trees, each with a vertical rectangular plane representing a LiDAR scan. The 'Xfrog' row shows three trees, each with a sphere representing a point cloud or similar data source.

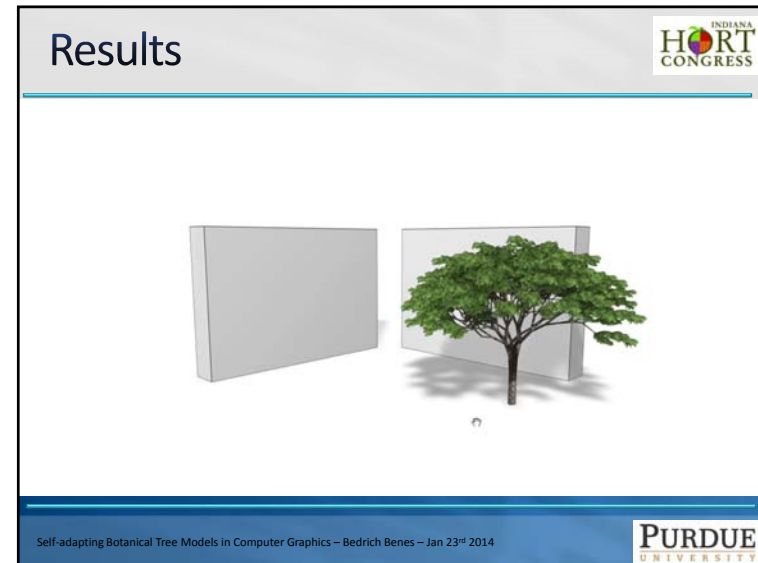
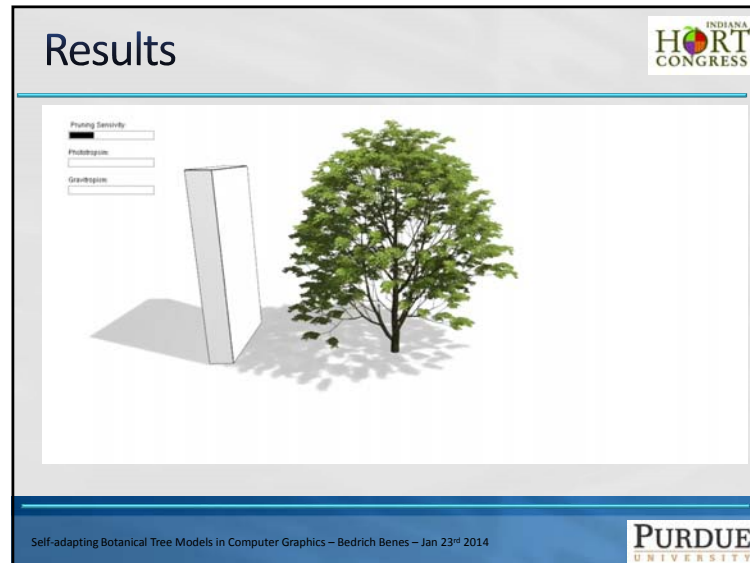
Results

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Detailed description: This slide displays a 3D architectural rendering of a house with a complex roof structure, including a gable and a dormer. The house is shown from a perspective view, highlighting its geometric forms.



Conclusions

- Visual modeling is a very strong concept
- Precise geometry can improve biological models
- Inverse methods *are very interesting*
- Computer graphics deals with light and geometry, so does biology...

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